Restricted Circulation

This paper is not an official document: it is for information only and reference cannot be made to it in any printed publication without the permission of the author.

AGRICULTURAL MEMORANDUM NO. 537

Crop production in higher latitude, maritime regions

by R W Gloyne

IV. Temperature - spatial and temporal variation

The relevance of temperature to plant growth and production needs no emphasis; however the precise role played by air, tissue and soil temperature in plant processes and functions continues to be a subject of study.

Amongst the phenomena involved are:

soil temperature in relation to:

germination

root growth and activity

nutrient uptake

biochemical activity

air temperature at various levels (usually the real interest is in tissue temperature to which air temperature is more or less closely coupled - see eg Gates, 1968); mean values, extreme values, threshold values;

in relation to:

photo-chemical processes (outstandingly, photosynthesis),

thermo-chemical processes - leaf expansion, development and growth generally; the translocation and partitioning of photosynthates;

ripening, drying, conditioning of plants.

Geographical distribution of air temperature: seasonal variation

Although the broad regional pattern of air temperature will be well-known, several aspects deserve specific mention.

In Tables 1 and 2 means of monthly values of daily mean, daily maximum and daily minimum are set out for a selection of stations located on Fig 1. The stations have been listed in five groups, viz:

four situated at or north of the Arctic Circle (Nos 1 to 4)

two at about 64°N (Nos 5 and 6)

nine between about 57°N to 60°N (Nos 7-16)

nine located within a few degrees latitude of 55°N (Nos 17-26)

Within each group, stations are listed from west to east (west coast of N America to east coast of Asia) listed downwards in Tables 1 and 2. Periods used for computing averages vary somewhat; in Table 1 it has been possible to adopt 1931-60 for most stations, however this has not been possible for many of the entries in Table 2 and hence Tables 1 and 2 are not strictly comparable.

Although the swings of long-period average temperature during the 20th century have been agriculturally significant in many respects, for the immediate purpose of broad-scale geographical comparisons such differences may be ignored.

In the first group there is a sharp contrast in the general level of mean temperature between Barrow (No 1) facing the ice-bound sea, and the three Scandinavian stations (Nos 2, 3, 4): each of these has some period of the year with a mean temperature exceeding thresholds of both 6°C and 10°C. Within the Scandinavian group Tromso (No 2) can be distinguished from the other two stations; its maritime climate being reflected in the annual range (15.3°C) compared with the 28°C or more at the other three stations, and similar remarks may be made regarding mean daily maxima and mean daily minima. It will be noted that whilst at the Scandinavian stations (particularly inland Sodenkyla No 4), afternoon maxima in the summer certainly approach those of southern Britain (and exceed those of northern Britain), there are only two months at Barrow when mean daily maxima exceeds 7°C. Mean daily minima at Barrow are also in sharp contrast with the other three of this group.

In the second group ((the markedly maritime Reyjavik (No 5) and coastal Trondheim (No 6)) mean summer temperatures are at the same general level as for Nos 2, 3 and 4: in other seasons temperatures run at a higher level. At Trondheim mean daily minima in winter and mean daily maxima in summer are respectively lower and higher than at Reyjavik. This rather more "continental" character of Tronheim doubtless arises from the presence of an extensive land-mass to the east of the station.

The third group (lying between 57° and 60½°N) show two particularly interesting contrasts:

(i) that between western coastal stations (Nos 7, 11, 12) and the 'within-continent' stations (Nos 8, 9) and in winter Nos 13, 14 and 15.

(ii) the distinction between stations on the western coasts of land masses Nos 7, 11, 12) and on the eastern coasts (10 and 16); at these latter the cooler summers of coastal areas compared with inland, are not balanced by relative warmth in winter.

The final group (covering latitudes 51½ to 56°N) again reveal the contrasts mentioned above in (i) and (ii). Concerning eastern Canada we quote "the climate of all Labrador is severe (Climate of Canada 1960). Even in coastal Newfoundland (most of which is south of 50°N), mean January temperature averages -6.7° to -3.3°C in the south whilst mean July temperature, even inland in the Island is about 15.5°C. Further south in Nova Scotia (lats 44-46°N) January mean temperature is about -6.7°C to -3.3°C and July temperature 16.7 to 18.9°C.

These "within-zone" contrasts are underlined by the following illustrative data:

	Lat	Mean Jan Temp (°C)	Mean July Temp (°C)
W Coast of Canada			
Prince Rupert	54° 17' N	2.1	13.4
Vancouver	49° 17' N	3.1	18.0
E Coast of Canada			
Hopedale	55° 27' N	-17.5	11.4
Goose Bay	53° 19' N	-18.2	15.8

	Lat	Mean Jan Temp (°C)	Mean July Temp (°C)
W coast British Isles			
Lerwick	60° 08' N	3.1	12.0
Glenamoy	54° 15' N	4.7	13.4
W coast Norway			
Bergen	60° 24' N	1.5	15.0
Stavanger	58° 57' N	0.7	14.7

A scrutiny of the mean maximum temperatures for the month of July (Table 2) illustrates the contrast in summer between inland and coastal areas.

e.g. inland	Sodankyla	(67½N)	-	20.0°C
	Fort Nelson	(58¾N)	-	23.3°C
	Churchill	(58¾N)	-	17.8°C
"coastal"	Reykjavick	(63½N)	-	14.4°C
	Sitka	(57°N)	-	12.8°C
	Hebron	(58°N)	-	13.3°C
	Lerwick	(60N)	-	14.4°C
	Okhotsk	(59½N)	-	13.9°C

although we note the apparently favoured situation of Norway

	Trondheim	(63½°)	-	18.2°C
	Bergen	(60½N)	-	22.2°C

The contrast between the western and eastern coasts of continental land masses is most marked in winter and well illustrated by the mean daily maximum temperature for January.

			°C
W Canada	Sitka	(57°N)	3.3
	Prince Rupert	(54¼)	4.7
W Europe	Lerwick	(60N)	5.0
	Bergen	(60½N)	6.1
E Canada	Hebron	(58¼N)	-17.2
	Hopedale	(55½N)	-13.3

E Asia	Okhotsk	($59\frac{1}{2}$N)	-21.1
	Usk-Kamchetsk	($56\frac{3}{4}$N)	- 8.9
	Petroparlorsk	(53N)	- 5.0

The influence of topography upon temperature

The importance of the influence of topography upon temperature is well recognised. The main topics of interest under this head are probably:

(a) height above mean sea-level;

(b) distance from the sea;

(c) the degree of, an orientation of, slope (more important for near surface and ground temperature than for air temperature).

(a) The variation with height above sea-level has been extensively documented. On broad average terms mean daily temperature falls off at the rate of 0.6°C to 0.7°C per 100 metres (1°F per 280-300 ft). Day maxima follows this rule fairly satisfactorily. However night minima departs from it in situations where on quiet, clear nights cold air can gravitate and stagnate.

(b) The influence of the sea (and large inland waters) is also well-known, but presents complications, and is much less well documented. The satisfactory expression of the influence involves:

(i) relationships between the geometry of the coastline and the degree of penetration of maritime influences (notably the sea/land breeze phenomena). Topographic situations range from extensive flat coastal plains and estuaries to a highly dissected coast-line such as Norway and west Scotland. An important special case is the extent to which a high, unbroken cliff face prevents or hinders the penetration of maritime influences.

(ii) relationship between the physiography of the area concerned and the weather and wind systems impinging upon it.

Phenomena under (i) are most clearly expressed under conditions of clear sky and slack pressure gradients. In middle latitudes the horizontal extension of land-sea

breeze circulation rarely exceeds 40–50 km although in sub-tropical and tropical areas it reaches 100–150 km (Flohn, 1970) as evidenced by the inland penetration of advective fog in the USA (see George quoted in Malone 1951 p1186). Flohn also states that in southern England the inland penetration of a sea-breeze "front" is relatively slow viz not more than 6 km/hr. Spence (unpublished 1955) discussing maritime influences over the flat terrain of eastern England suggests a coastal strip from 2 to 4 miles deep, followed by an intermediate zone of width between 4 and 14 miles. In the highly complicated terrain of western Norway, maritime influences by no means penetrate the full extent of the fjords e.g. see discussion by Wielgolaski (1973) of fruit cultivation in the Sognefjord: such conclusions are reinforced by the spatial pattern of surface wind velocities in Norway. That quite minor obstructions e.g. a range of low coastal hills, a row of trees, can significantly reduce the penetration of maritime influence is evidenced by studies in Japan on the trapping of advective fog by tree belts (Various 1953).

(c) Not least in higher latitudes, the slope and orientation of the ground will have considerable influence upon temperature, and in particular that at or near the ground surface. Such effects are most marked in the high radiation conditions experienced within extensive land-masses, but do not appear to be negligible in maritime regions. In addition to solar radiation, other aspects of the weather (notably wind and precipitation) become influential and only in quiet, clear weather is there likely to be any close relationships between air (and soil) temperature and site geometry arising from the way in which the surface is presented to the solar beam.

There is a considerable amount of scattered information on near-ground temperatures on relatively small features (such as specially constructed mounds of earth) but little from natural landscapes. On the first Geiger (1965 p369 et seq) gives a useful selection on a range of scales (but in "continental" situations).

Geiger (ibid p426) quotes a run of day maximum temperatures in 4 sunny days in June at 40 cm from a forest floor in southern Germany as 3° to 3.5°C higher on the

south west slope of a hill compared with that recorded on the north-east facing slope (angle of slope 15° to 40°). For northern Britain, Richardson (1954 and 1956) examined conventional screen air temperatures on the west ("W") and east ("E") facing slopes of the north-south valley of the River Tyne near Alston (Cumberland). On 80% of occasions the day maximum at "W" exceeded that at "E" by at least ½°F (values appeared to be generally not greater than about 3°F; an extreme case was one of 18°F). Night minima showed no such definite tendency. As might be anticipated the contrasts at night were between the slope stations on the one hand and the river valley station (some 50 m lower) on the other. Taylor (1967) quotes surface temperatures on a roughly conical hill in west Wales. On a clear day the maximum temperatures were:

	Slope facing:-			
	North	East	South	West
	72½°F	73°F	100°F	86°F

and on a cloudy November day:

Maximum	51	51½	53	51
Minimum	41½	43	46	46

Slope induced temperature differences certainly do exist in maritime areas but adequate information for practical field conditions is sparse and quite inadequate for generalisation. In relation to plant growth, other features of the climate may well play a far more important role than does temperature. In many areas in western Britain the exposure of the western-facing slope to wind would appear to be of more significance to plant life than any advantage gained from a temperature differential.

References

Flohn H (1969) "Local Wind Systems" (p139 in) "World Survey of Climatology". Vol 2. Elsevier Press.

Geiger R (1965) "The Climate near the Ground" (revised Ed 1965) Harvard University Press. 611pp.

Gloyne R W (1972) Papers in Met Office (Agr Memo No. 514)

Malone T (Ed 1951) "Compendium of Meteorology" Am Met Soc. Boston, USA. (p1334).

Oliver J (1960) Altitudinal modifications of a maritime climate, with special reference to South Wales. UC Wales (Aberystwyth) Memo No. 3 (1960) Mimeo. pp6–14.

Richardson W E (1954) "Temperature differences in the south Tyne Valley, near Alston, Cumberland". Weather IX(3) March 1954 pp82–85.

Richardson W E (1956) "Temperature differences in the south Tyne Valley, with special reference to the effects of air-mass". Quart J Royal Met Soc 82 (No. 353) July 1956 pp342–348.

Spence M T (c. 1955) "Climate and proximity to the sea in E Anglia" MS. in Met Office.

Various (1953) Studies on Fog-preventive forest. (Vol III) Bull Govt For Exp Sta. No. 64. Tokyo. Oct 1953.

Wielgolaski F F (1972) "Development of Plum trees and the quality of fruit of the Plum variety "Victoria" in relation to soil and climate". Supplement to Vol 16 of Int J Biomet. Vol 5(1). p128–9.

Table 1. Average daily mean air temperature at selected stations °C

Station No	Place	Lat	Long	Ht above msl (m)	Jan	Apr	Jul	Oct	Annual	Range
1	Barrow	71.3°N	156.7°W	7	-26.8	-17.7	3.9	-8.6	-12.4	31.8
2	Tromso	69.7°N	18.9°E	45	- 2.7	1.0	12.0	3.7	3.3	15.3
3	Karasjok	69.5°N	25.5°E	129	-16.7	- 3.6	12.8	-2.2	- 2.8	29.2
4	Sodankyla	67.3°N	26.7°E	180	-13.5	- 2.1	14.7	-0.5	- 0.4	28.2
5	Reykjavik	64.2°N	21.9°W	28	- 0.4	3.1	11.2	4.9	5.0	11.6
6	Trondheim	63.4°N	10.4°E	127	- 3.4	3.2	14.4	5.1	4.9	17.8
7	Sitka	57.1°N	135.3°W	5	0.3	5.0	12.8	7.8	6.4	12.8
8	Fort Nelson	58.8°N	122.6°W	375	-22.4	1.2	16.8	1.2	- 1.1	39.2
9	Churchill	58.7°N	94.2°W	13	-27.6	-10.1	12.2	-1.4	- 7.0	39.8
10	Hebron	58.2°N	62.3°W	15	-20.8	- 7.8	8.3	-0.6	- 5.0	29.7
11	Lerwick	60.2°N	1.2°W	82	3.1	5.5	12.0	8.1	7.2	9.2
12	Bergen	60.4°N	5.3°E	43	1.5	5.8	15.0	8.3	7.8	13.5
13	Oslo	59.9°N	10.7°E	94	- 4.7	4.8	17.3	5.9	5.9	22.0
14	Stockholm	59.3°N	18.1°E	45	- 2.9	4.4	17.8	7.1	6.6	20.7
15	Helsinki	60.2°N	24.9°E	9	- 6.8	2.2	17.1	4.8	4.4	24.5
16	Okhotsk	59.3°N	143.3°E	5	-22.4	- 5.4	11.9	-2.1	- 4.6	35.5
17	P Rupert	54.3°N	130.4°W	52	2.1	6.3	13.4	8.8	7.7	12.0
18	G Prairie	55.2°N	118.9°W	668	-14.7	2.9	15.9	4.1	1.5	30.6
19	Hopedale	55.4°N	60.3°W	11	-17.5	- 5.3	11.4	2.2	- 1.9	28.9
20	Glenamoy	54.3°N	9.7°W	25	4.7	8.1	13.4	10.5	9.2	8.7
21	Dumfries	55.0°N	3.6°W	43	2.9	7.6	15.0	9.3	8.8	12.1
22	Eskdalemuir	55.3°N	3.2°W	242	1.4	5.8	13.3	7.6	7.1	11.9
23	Edinburgh	55.9°N	3.2°W	134	3.3	7.4	14.8	9.4	8.7	11.5
24	Copenhagen	55.7°N	12.6°E	13	0.1	6.6	17.8	9.3	8.5	17.9
25	Usk Kamchetsk	56.7°N	162.4°E	7	-12.8	- 3.6	11.4	1.9	- 0.8	25.3
26	Petroparlorsk	52.9°N	158.7°E	87	- 8.3	- 1.1	10.8	4.4	1.4	21.7
27	Kew	51.5°N	0.3°W	5	4.2	9.3	17.6	10.8	10.5	13.4

Table 2. Average maximum and minimum air temperatures °C at selected stations

Station No.	Maximum					Minimum				
	Jan	Apr	Jul	Oct	Annual	Jan	Apr	Jul	Oct	Annual
1	-23.0	-13.7	7.2	-5.9	-9.4	-30.6	-21.7	0.7	-11.2	-15.6
2	- 1.1	2.8	15.0	4.4	5.0	- 5.6	- 2.8	8.9	0.6	0.0
3	-11.7	2.2	18.3	1.7	2.2	-21.1	- 9.4	7.2	- 6.1	- 7.8
4	- 7.2	2.2	20.0	1.7	4.4	-16.7	- 8.9	8.3	- 3.3	- 5.6
5	2.2	6.1	14.4	6.7	7.8	- 2.2	0.6	8.9	2.2	2.8
6	- 0.6	7.2	18.9	7.8	8.3	- 5.6	0.0	10.6	2.2	1.7
7	3.3	8.9	16.1	11.1	10.0	- 2.8	1.1	9.4	4.4	2.8
8	-17.4	7.9	23.1	7.1	4.6	-26.2	- 5.3	9.9	- 3.9	- 6.6
9	-23.4	- 7.2	17.7	1.5	-3.4	-31.3	-16.6	7.6	- 4.2	-11.4
10	-17.2	- 3.3	13.3	2.2	-1.1	-24.4	-12.2	3.3	- 3.3	- 8.9
11	5.0	8.1	14.4	10.1	9.4	1.2	2.8	9.7	6.2	5.0
12	6.1	12.8	22.2	13.9	13.9	- 2.8	1.1	10.6	3.3	2.8
13	- 1.1	10.0	22.8	9.4	10.0	- 6.7	1.1	13.3	2.8	2.2
14	- 0.6	7.2	21.1	8.9	8.9	- 5.0	0.0	12.8	3.9	2.8
15	- 2.8	6.1	21.7	7.2	7.8	- 8.3	- 0.6	13.9	2.8	1.7
16	-21.1	- 1.7	13.9	0.6	-2.2	-27.2	-12.2	8.9	- 6.1	- 9.4
17	4.7	10.1	17.2	11.8	11.1	- 0.6	2.6	9.7	5.7	4.4
18	- 8.8	8.7	22.7	9.9	7.6	-20.5	- 2.8	9.2	- 1.8	- 4.6
19	-13.3	- 1.1	15.6	5.0	1.7	-21.7	- 9.4	7.2	- 0.6	- 5.6
20										
21	5.6	11.6	18.8	12.7	12.3	0.2	3.6	11.2	6.0	5.3
22	4.0	10.4	17.7	11.2	10.9	- 1.3	1.3	8.9	4.1	3.3
23	5.5	10.8	18.4	12.1	11.6	1.1	4.0	11.2	6.7	5.7
24	2.2	10.0	22.2	11.7	11.1	- 1.7	2.8	12.8	5.6	5.0
25	- 8.9	0.6	13.9	5.6	2.8	-16.7	- 7.8	8.9	- 1.7	- 4.4
26	- 5.0	1.7	13.3	7.8	4.4	-11.7	- 3.9	8.3	1.1	- 1.7
27	6.4	13.2	21.8	1.1	13.9	1.9	5.3	13.4	7.5	7.0

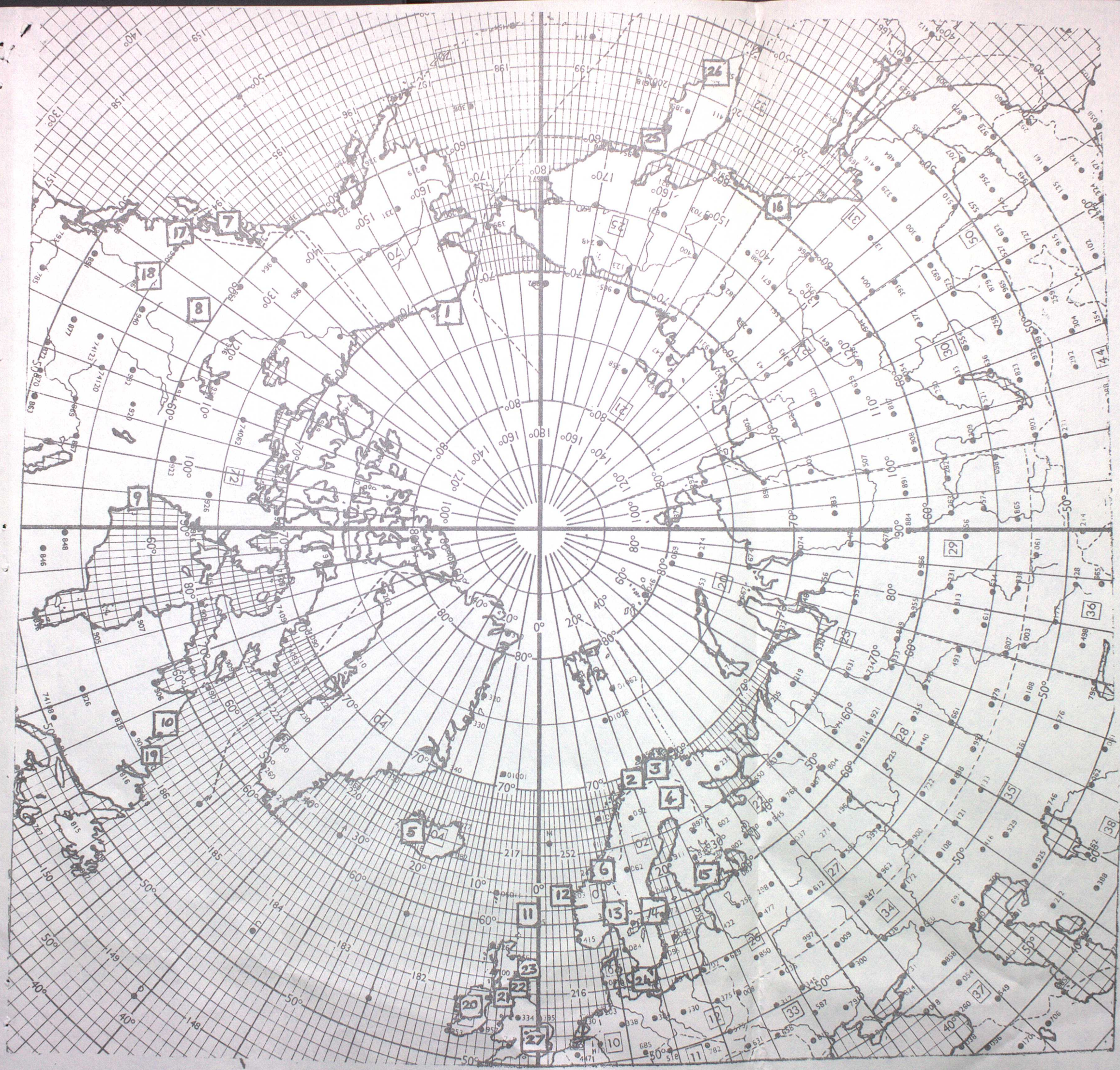

Fig 1. Location of stations for which temperature dated quoted in Tables 1 and 2. For details see Table 1 and text.

RE 20753 150 4/73 TBCL